Evaluation of Temperature Management Actions at Shasta Dam

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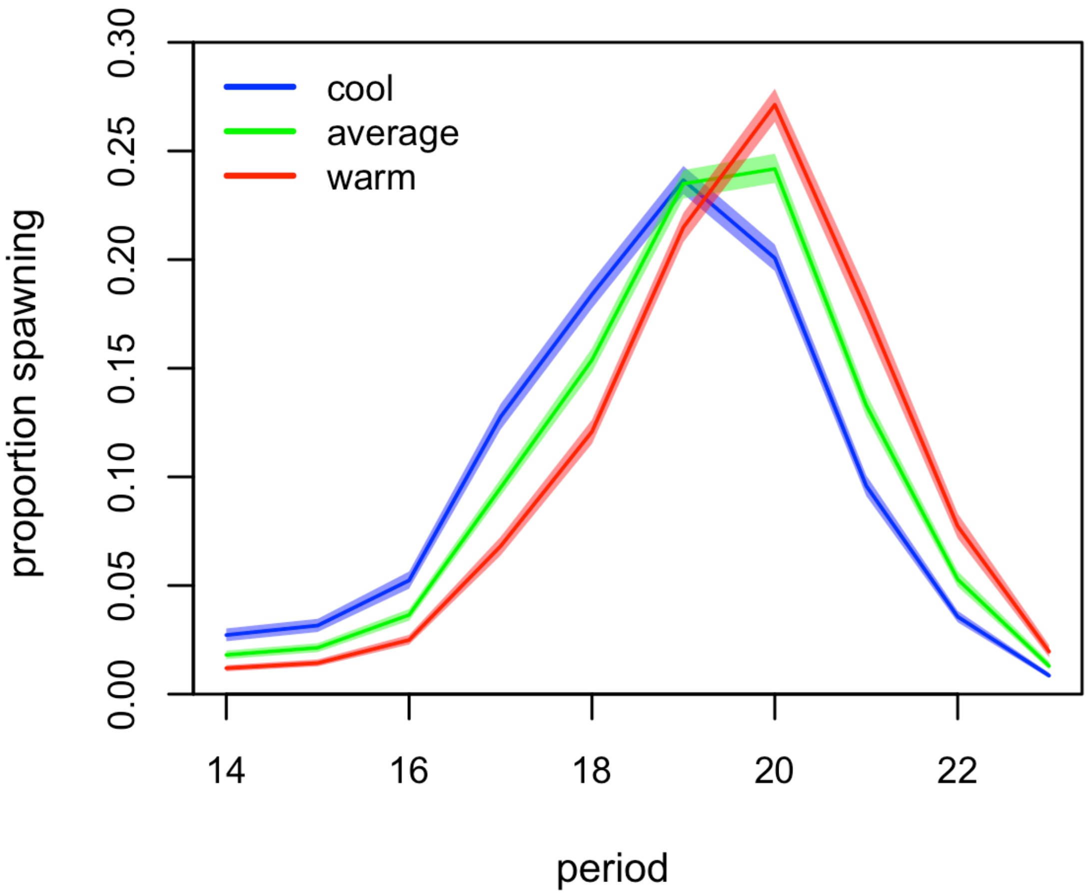
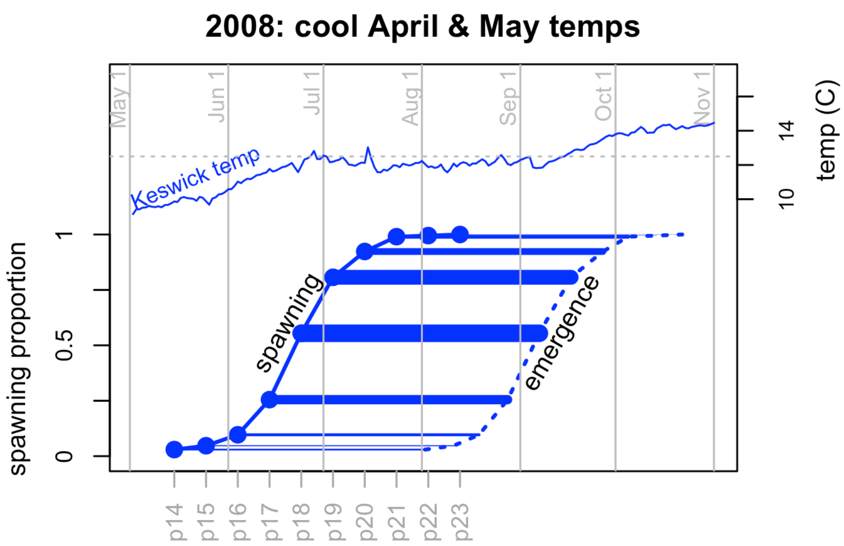
Background

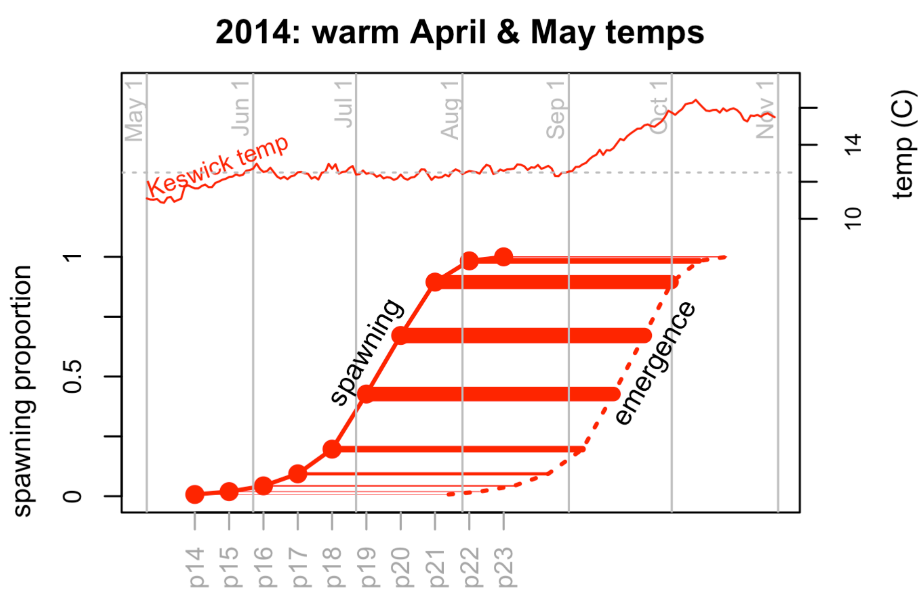


- Warmer April and May temperatures lead to later spawn timing

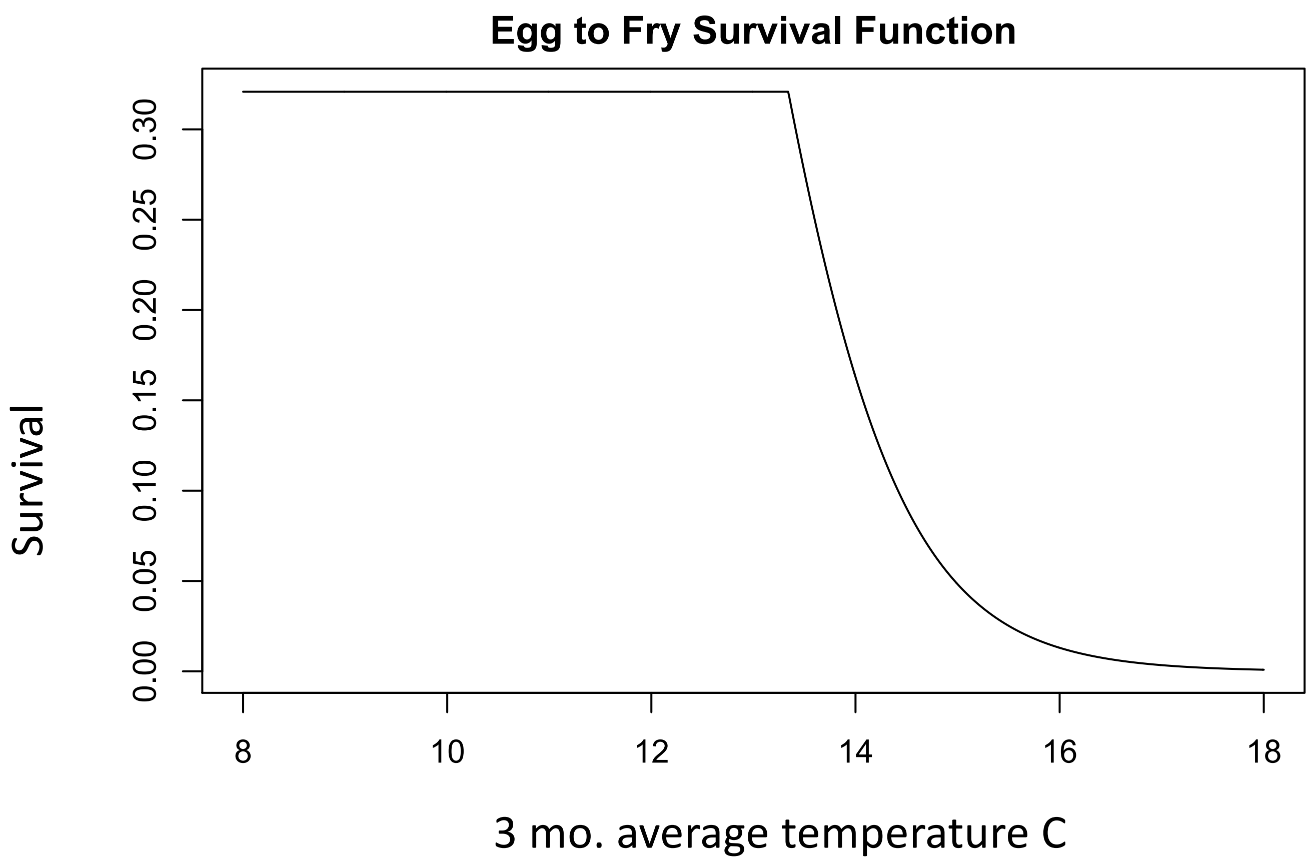
Exposure to thermal conditions given spawn timing

- In hot, dry conditions (e.g., 2014) , later spawning can lead to greater exposure

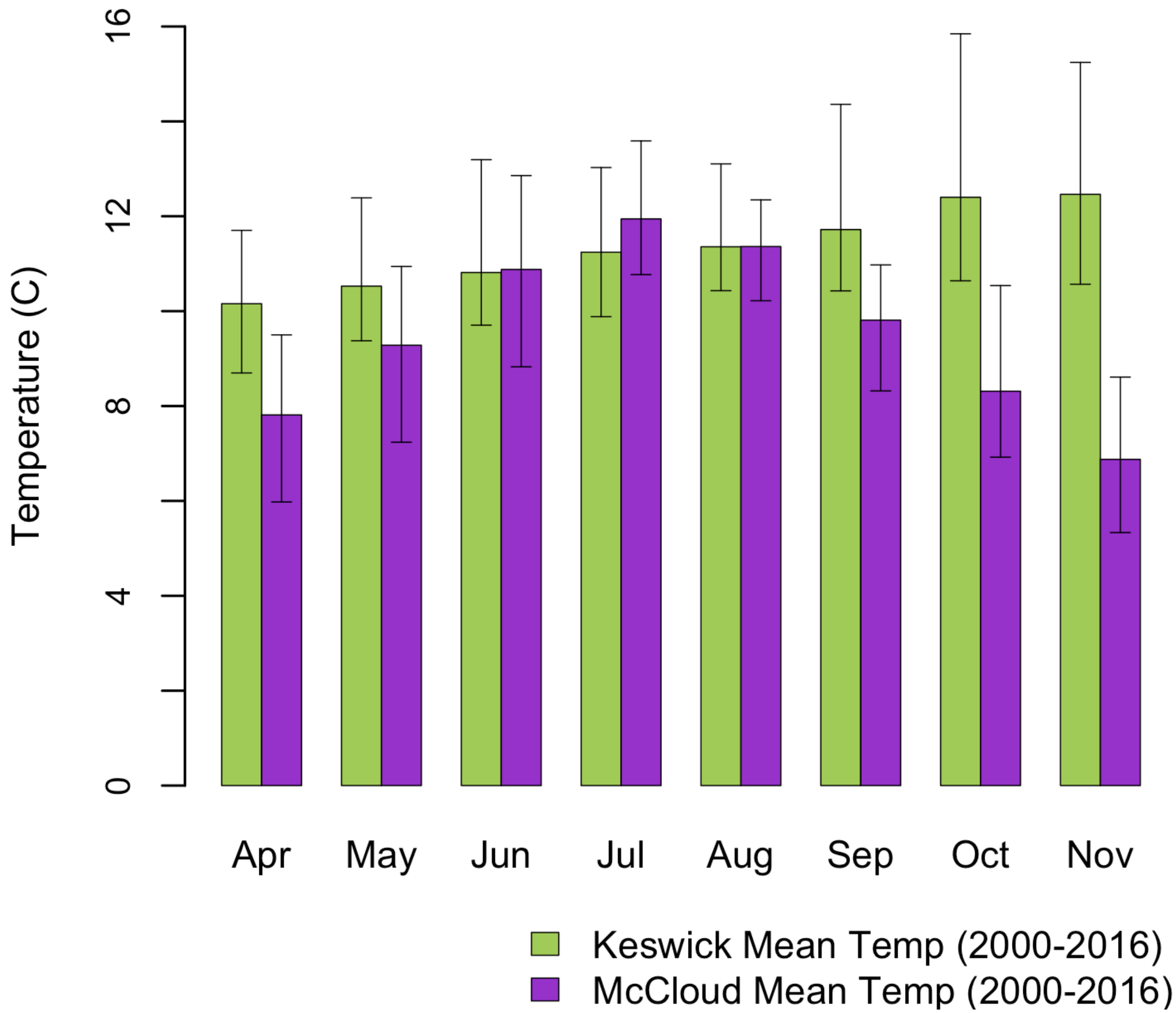




Egg to fry survival function



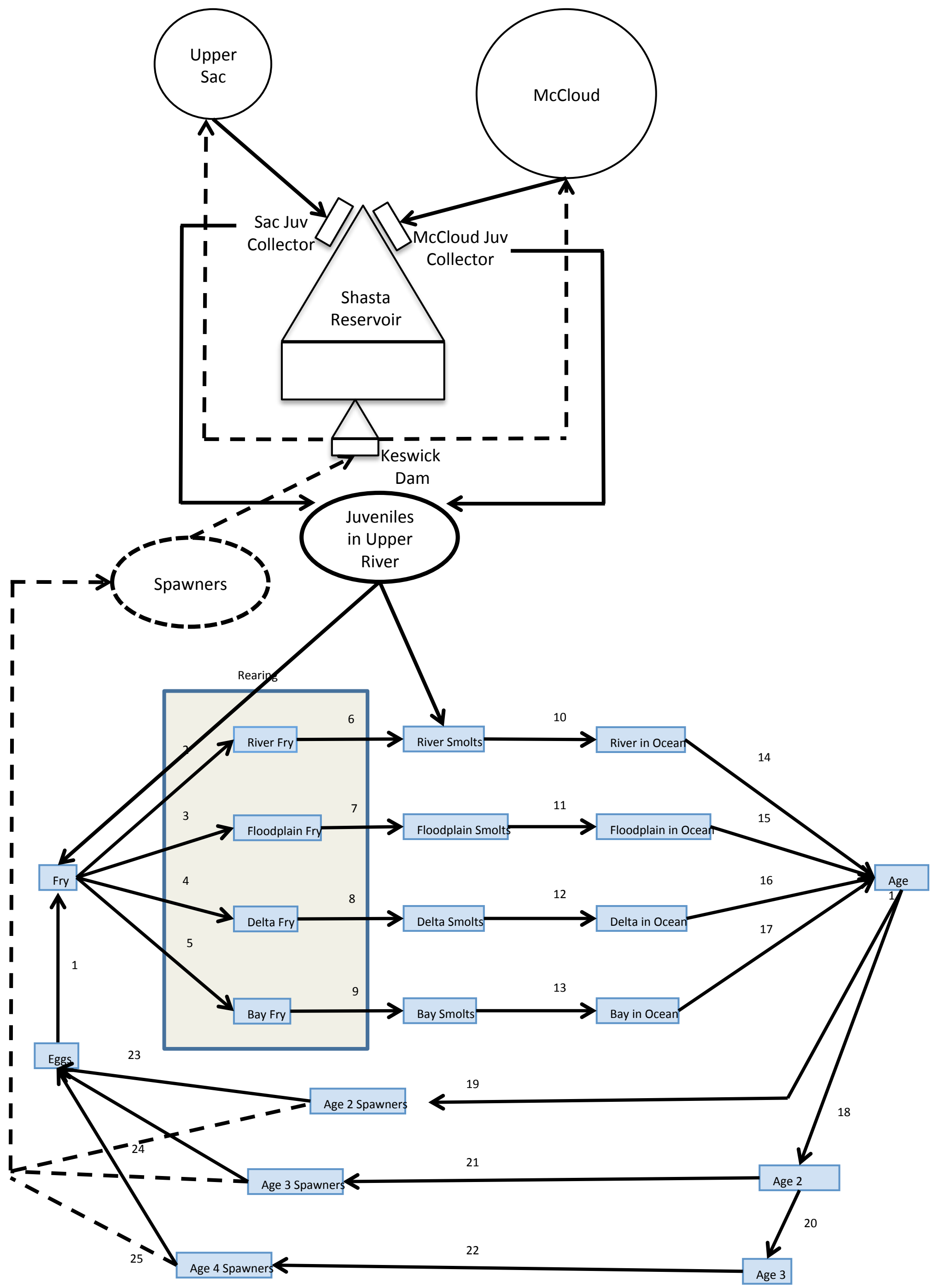
Reintroduction
Temps - Keswick versus McCloud



Reintroduction Model

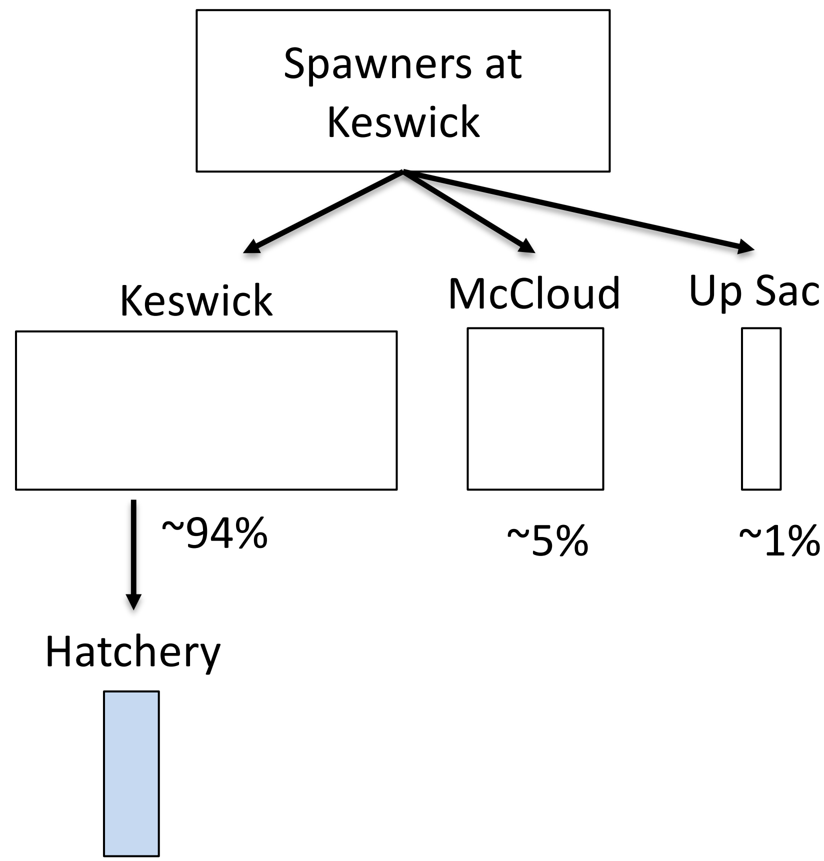
<u>Objectives:</u>

- Link reintroduction to appropriate life cycle stages in the existing life-cycle model
- Develop estimates of fish passage collection efficiency and survival for inclusion in the life cycle model
- Determine whether the reintroduction can lead to a sustainable population



Dynamic reintroduction in severe critical year (1977)

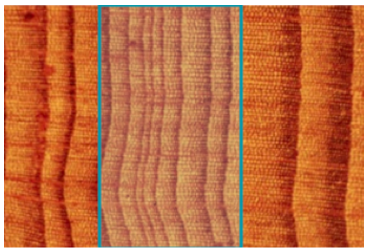
- Spawners return to Keswick
- Allotted to populations based on capacity
- Hatchery fish taken from remaining Keswick spawners

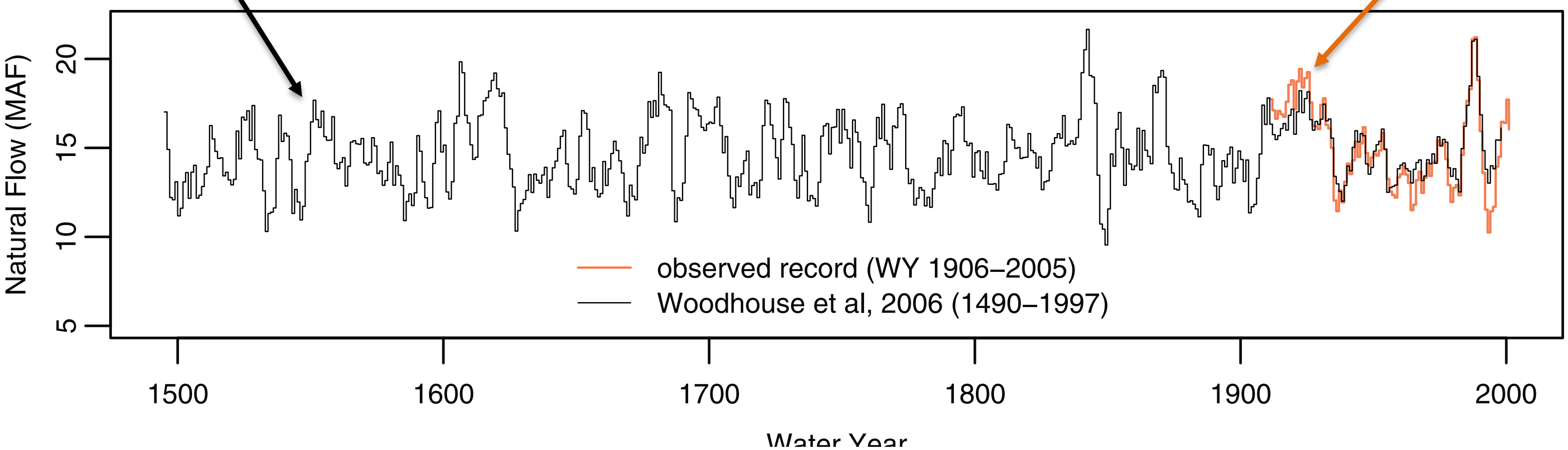


Developing hydrologic traces

- We want to evaluate management actions over multiple hydrologic conditions
  - Incorporates hydrologic variability rather than a single observed realization
  - Provides a more robust evaluation of the actions
- We developed a set of 100 hydrologic traces, each 100 years in length, that are consistent with historical hydrology

Relate paleorecord to streamflow
(Meko et al. 1995)



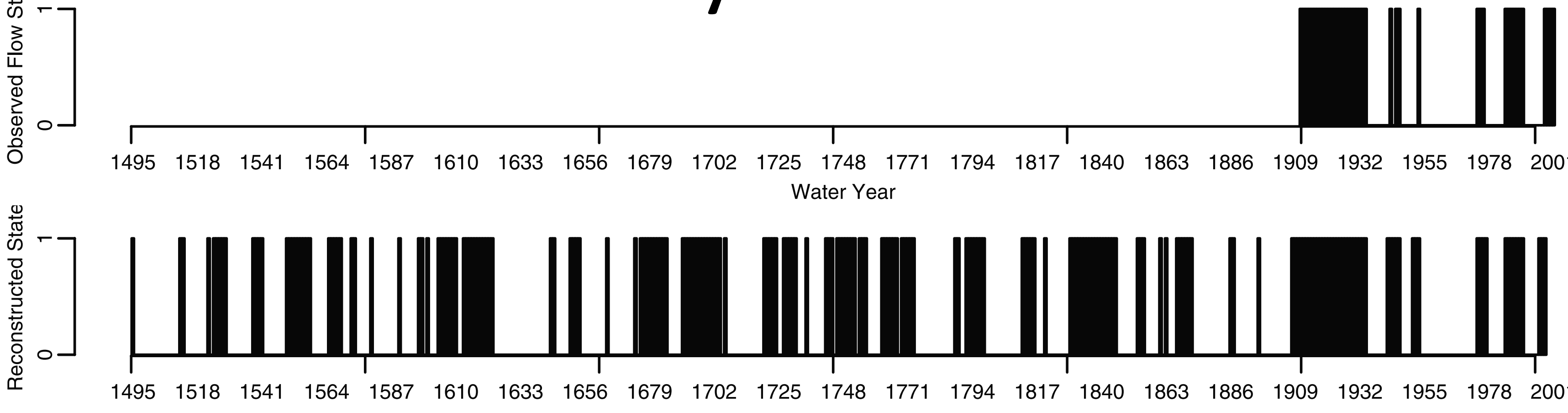


Meko, D., C. W. Stockton, and W. R. Boggess (1995), The tree-ring record of severe sustained drought, Water Resour. Bull., 31(5), 789–801.

Source:environmentalbrigade.wordpress.com

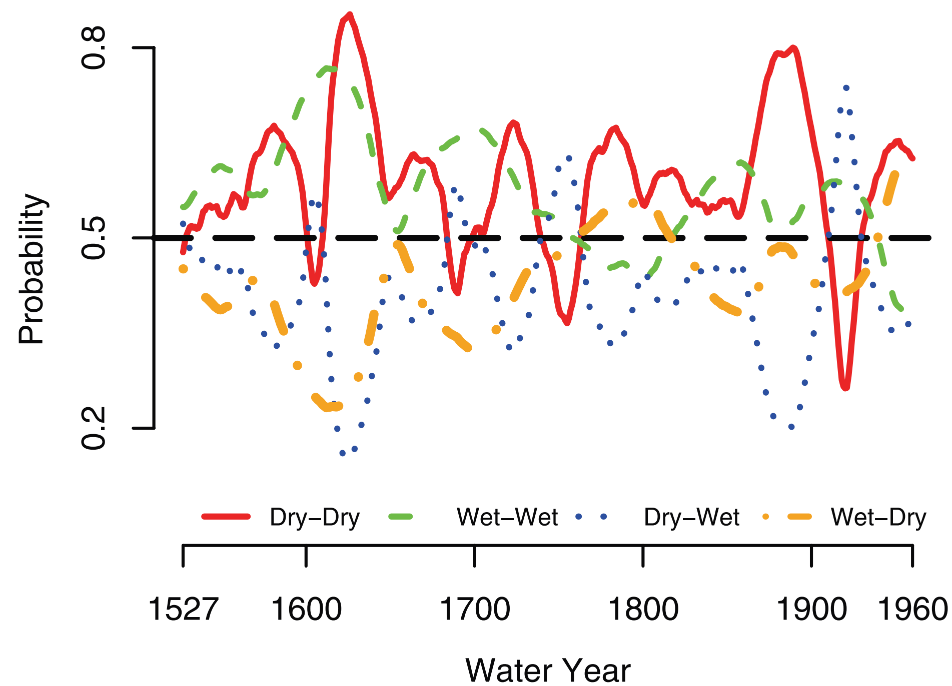
Source: DWR

Model transitions between wet and dry states

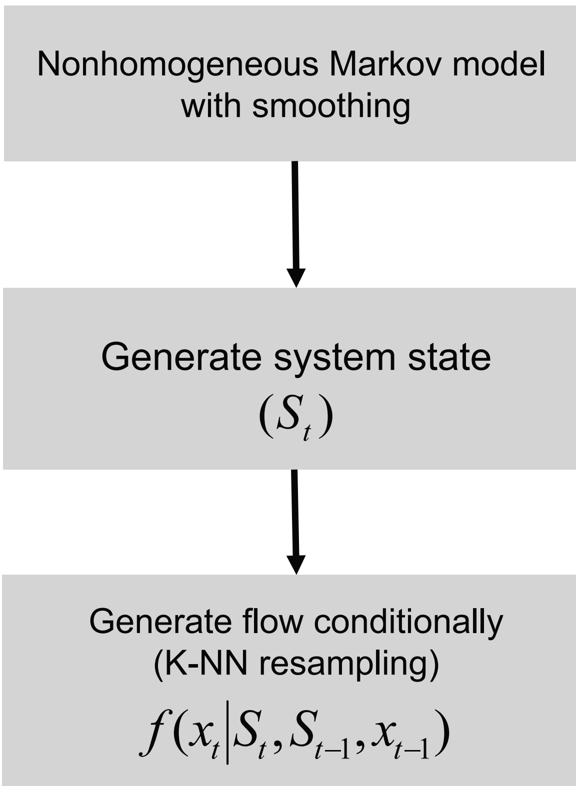


Wet = above median flow

Dry = below median flow



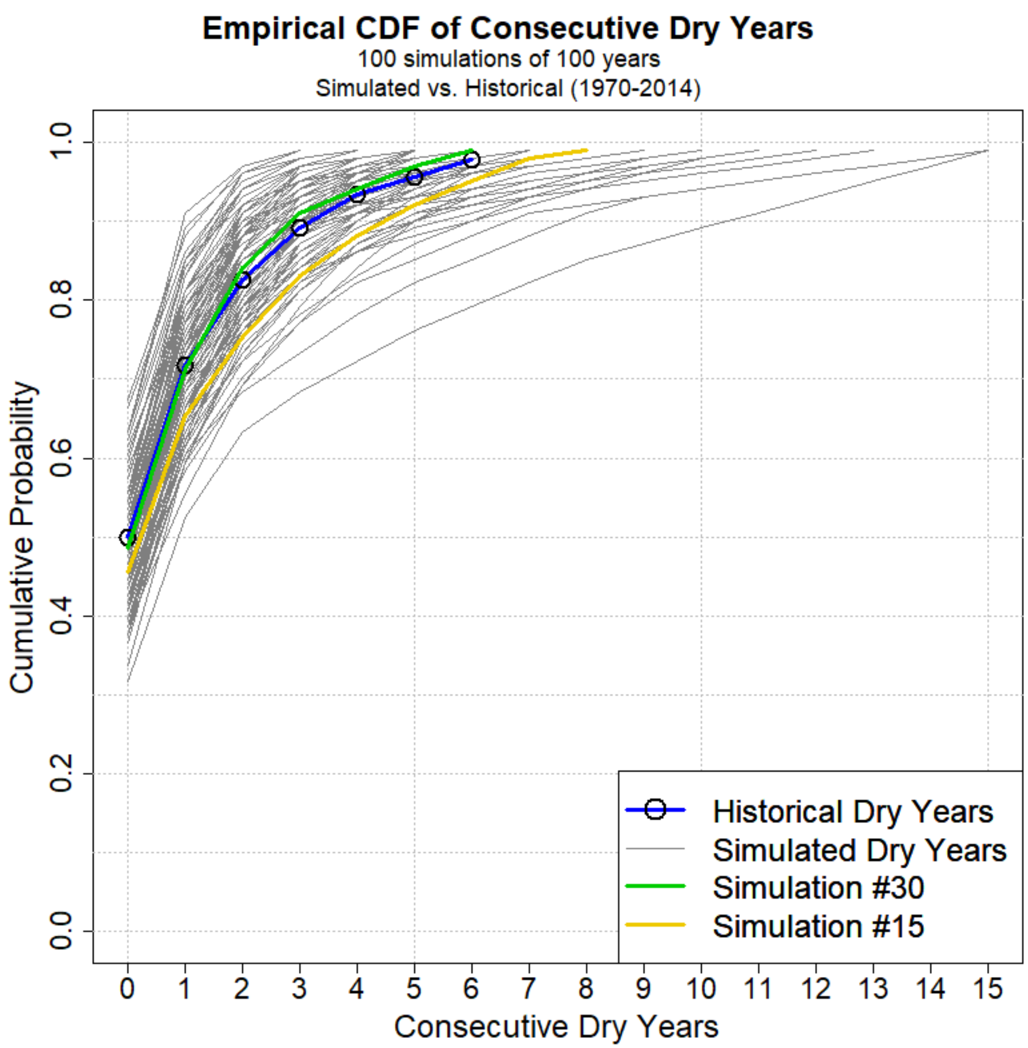
Selecting Years from the Observation Period
(Prarie et al. 2008)



- Use a bootstrap resampling approach with replacement
- Given the transition (e.g., wet -> dry), select years that are closer in time

Prairie, J., K. Nowak, B. Rajagopalan, U. Lall, and T. Fulp (2008), A stochastic nonparametric approach for streamflow generation combining observational and paleoreconstructed data, Water Resour. Res., 44

Simulating hydrologic traces for the Sacramento River



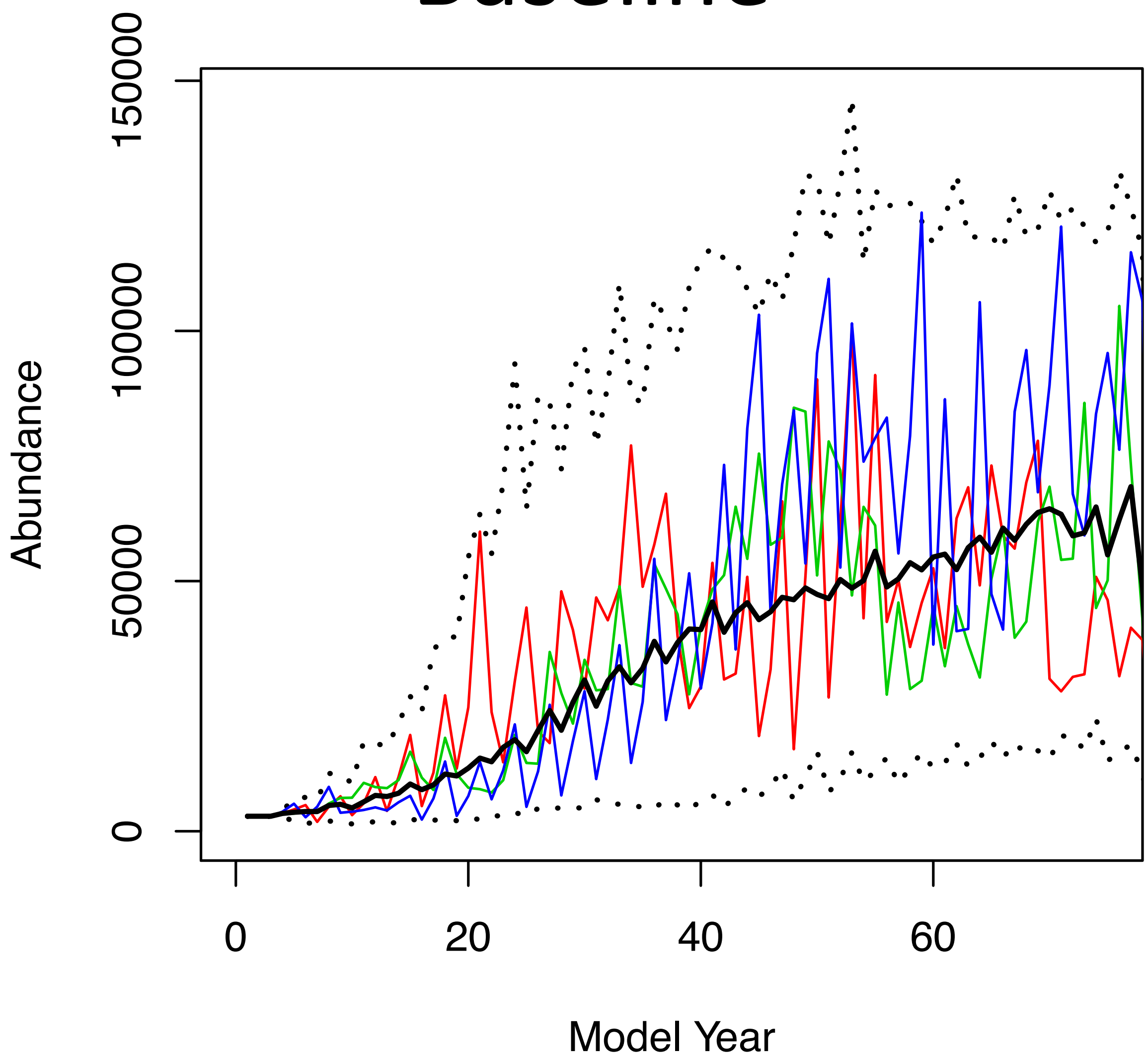
- Two-state non-homogeneous Markov transition matrix for wet/dry years from 900-2012 4-Rivers index
- Hydrologic resampling for selecting specific years from 1970 – 2014
- Performed by Lynker

What are some management actions to reduce thermal mortality below Keswick?

Table 1: Management actions explored in this analysis and their definitions. Actions include modification of Shasta temperature releases only, and modification of releases in combination with reintroduction.

Action	Definition
Action 1	-1 C in July -1 C in August with +1 C in June and Sept for all years
Action 2	Action 1 but just in Critical years
Action 3	-1 C in April +1.5 C in September for all years
Action 4	Action 3 but just in Critical years
Action 5	Action 3 in all but Critical years
Action 1R	-1 C in July -1 C in August with +1 C in June and Sept for all years with reintroduction
Action 2R	Action 1 but just in Critical years with reintroduction
Action 3R	-1 C in April +1.5 C in September for all years with reintroduction
Action 4R	Action 3 but just in Critical years with reintroduction
Action 5R	Action 3 in all but Critical years with reintroduction

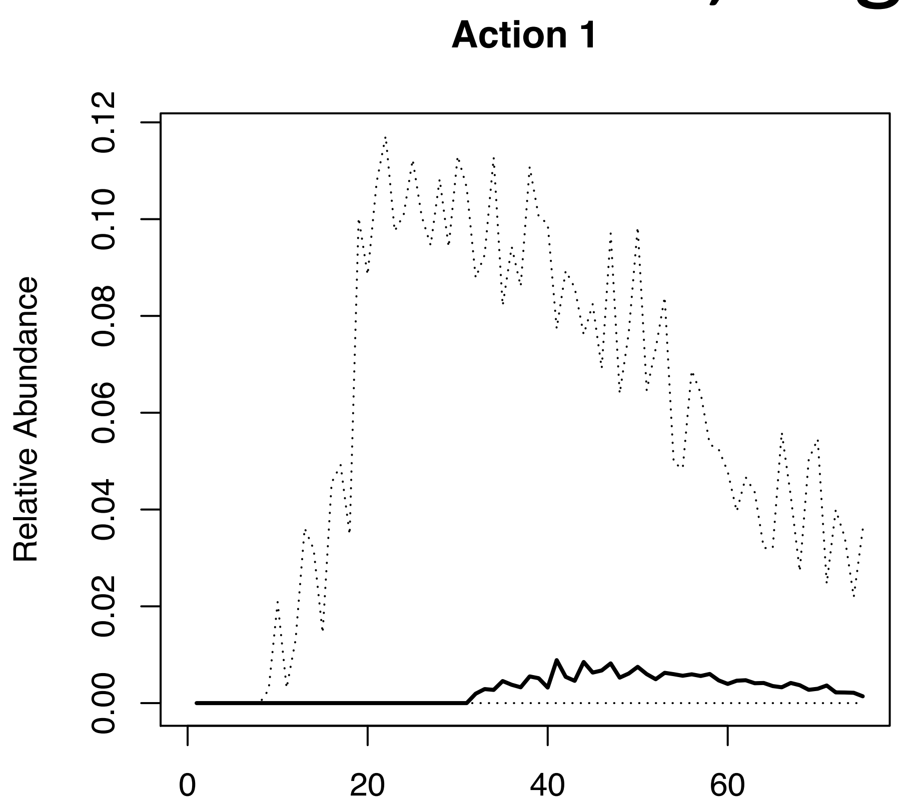
Preliminary Results
Baseline



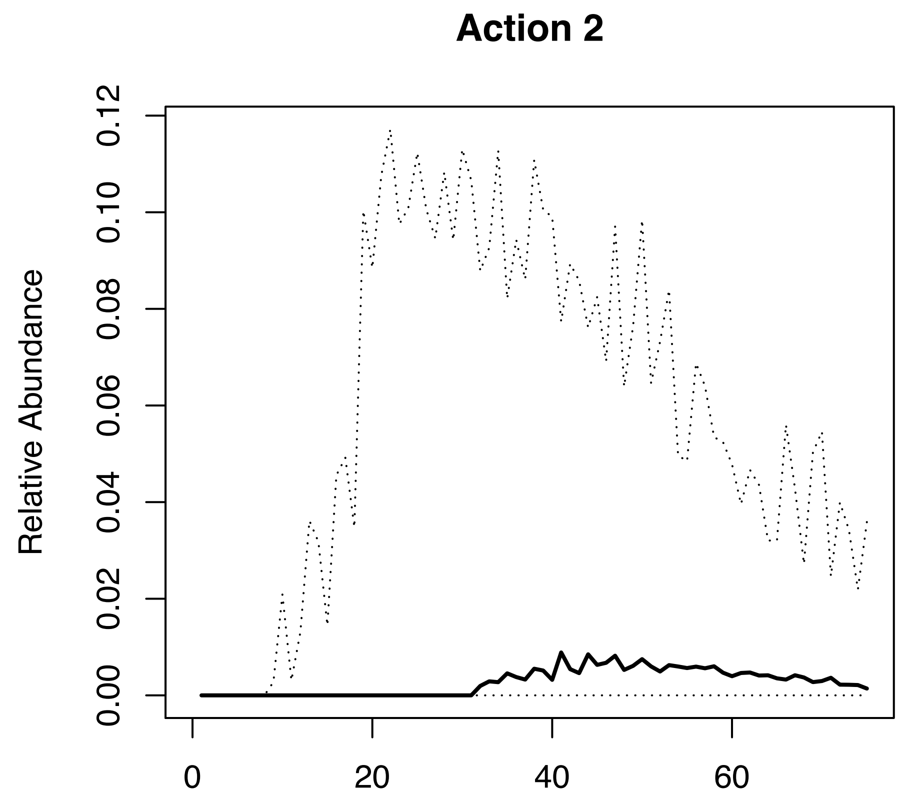
Results - Actions 1 thru 5

Action	Mean	Pr(Action > Baseline)
1	0.274 %	0.74
2	0.274 %	0.74
3	-20.2 %	0.00
4	-4.46 %	0.00
5	-16.5%	0.00

Preliminary Results Actions 1&2
-1C Jul,Aug, +1C Jun,Sep

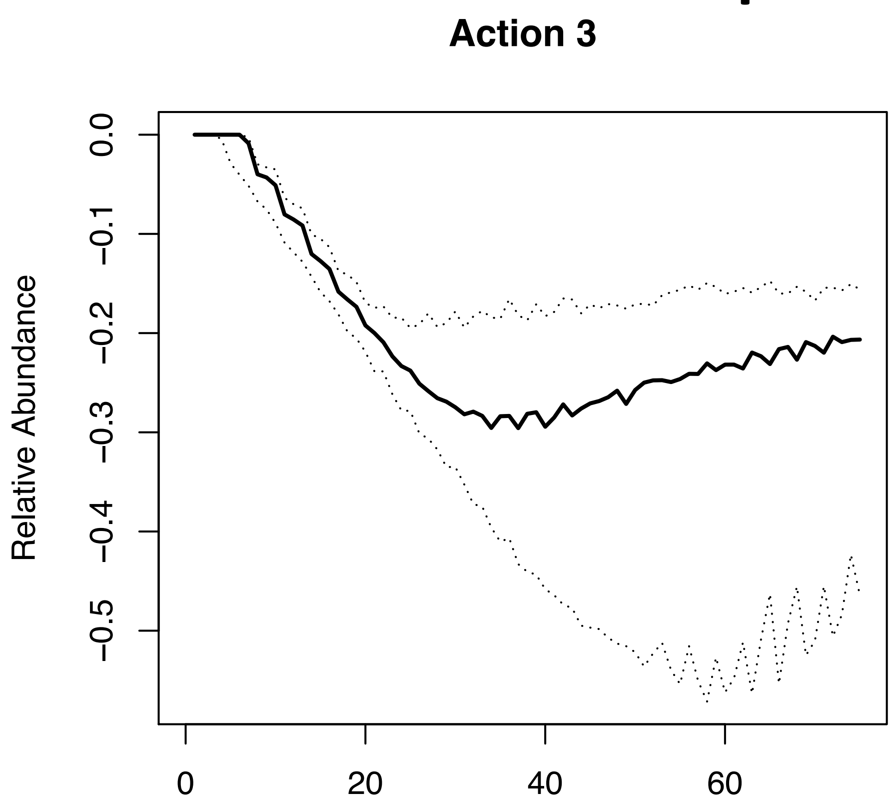


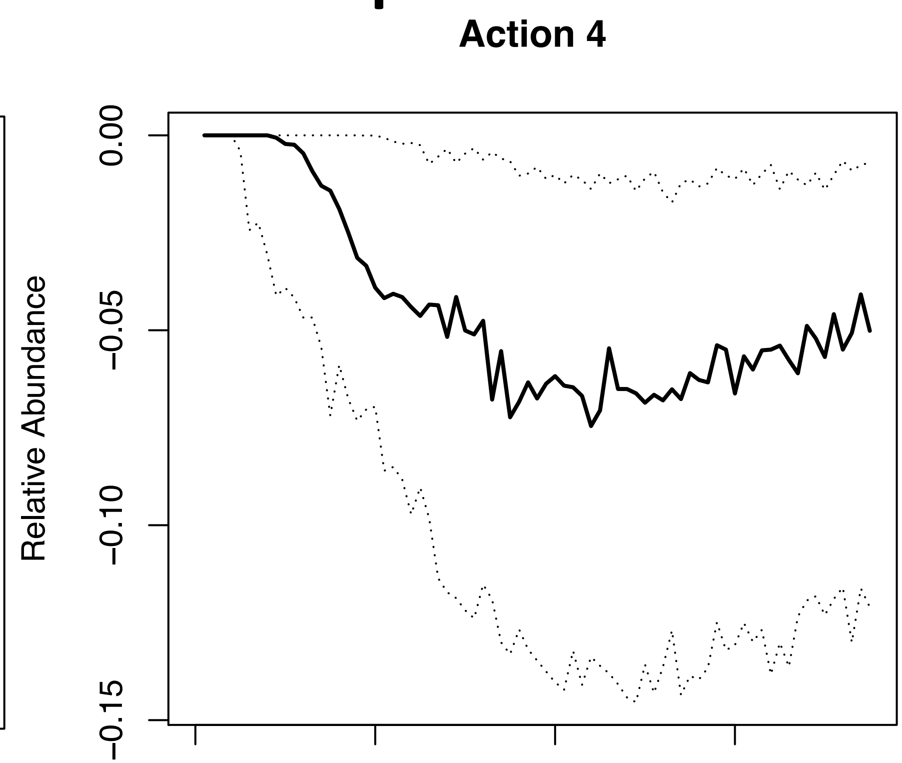
Action in
All Years



Action in
Critical Years

Preliminary Results, Actions 3&4
-1C Apr + 1.5C Sept





Action in All Years

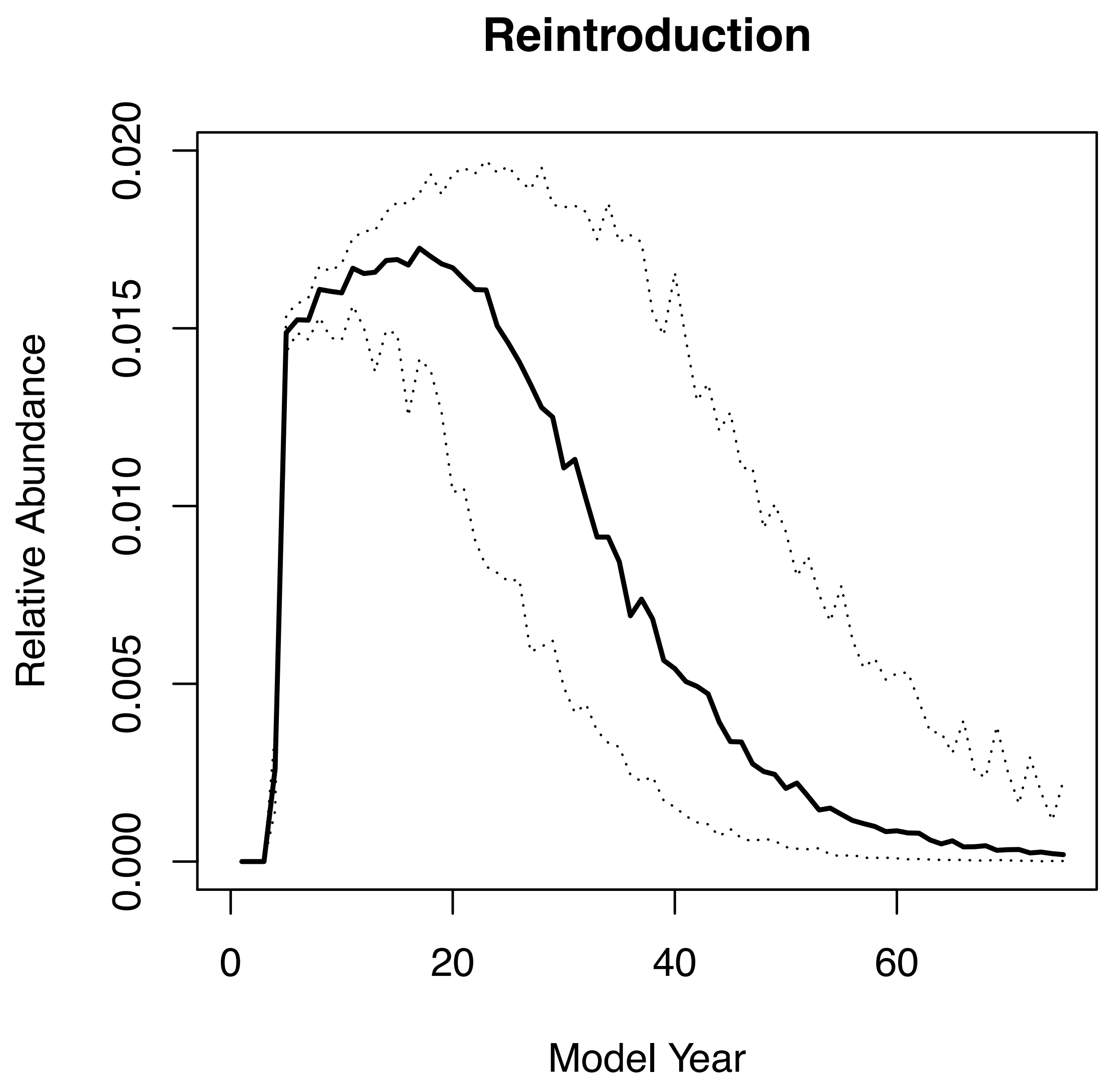
Action in Critical Years

Results – Actions with Reintroduction

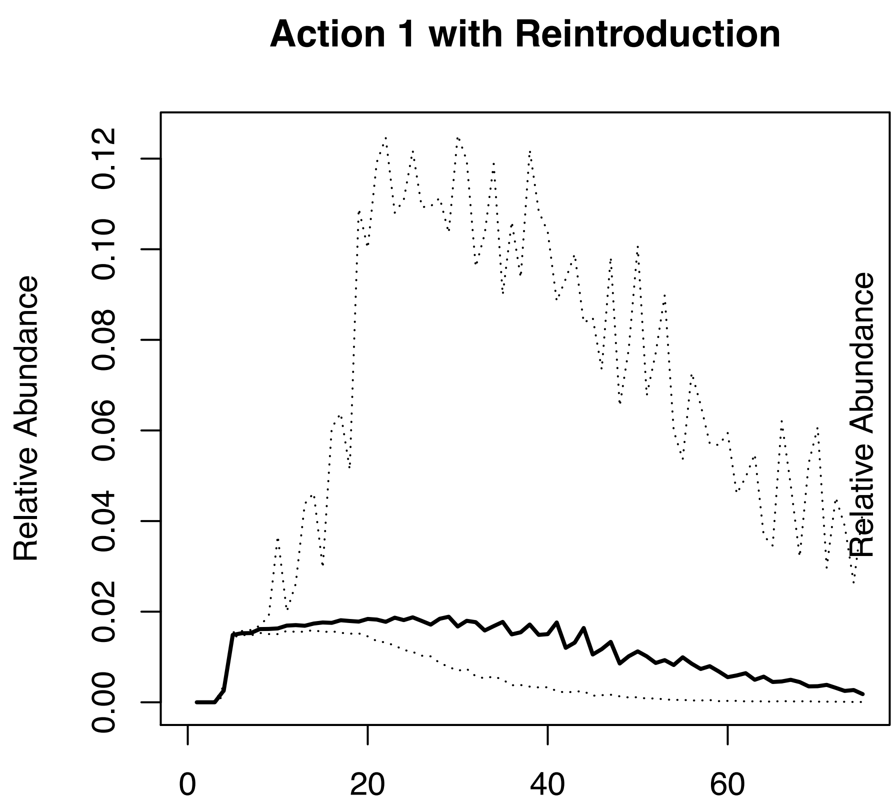
Action	Mean	Prob.Action
Reintroduction	0.722 %	0.76
1	1.18 %	0.76
2	1.18 %	0.76
3	-19.5 %	0.02
4	-3.69 %	0.05
5	-16.5 %	0.04

Dynamic Reintroduction

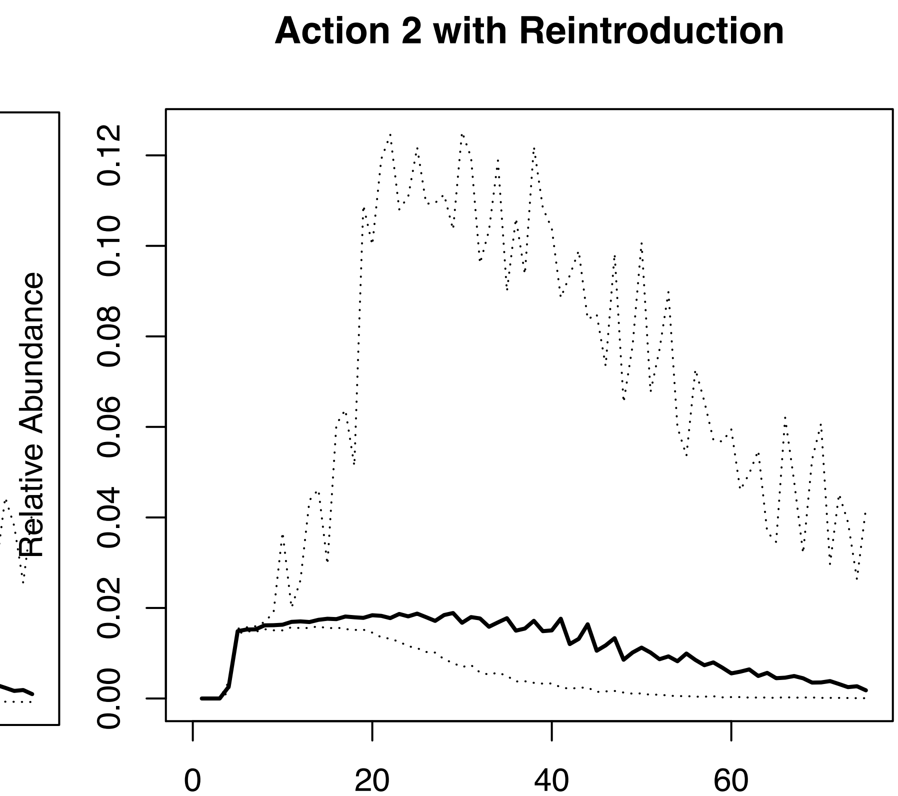
Reintroduction implemented in strong Critical (1977)



Preliminary Results
-1C Jul,Aug, +1C Jun,Sep & Reintro



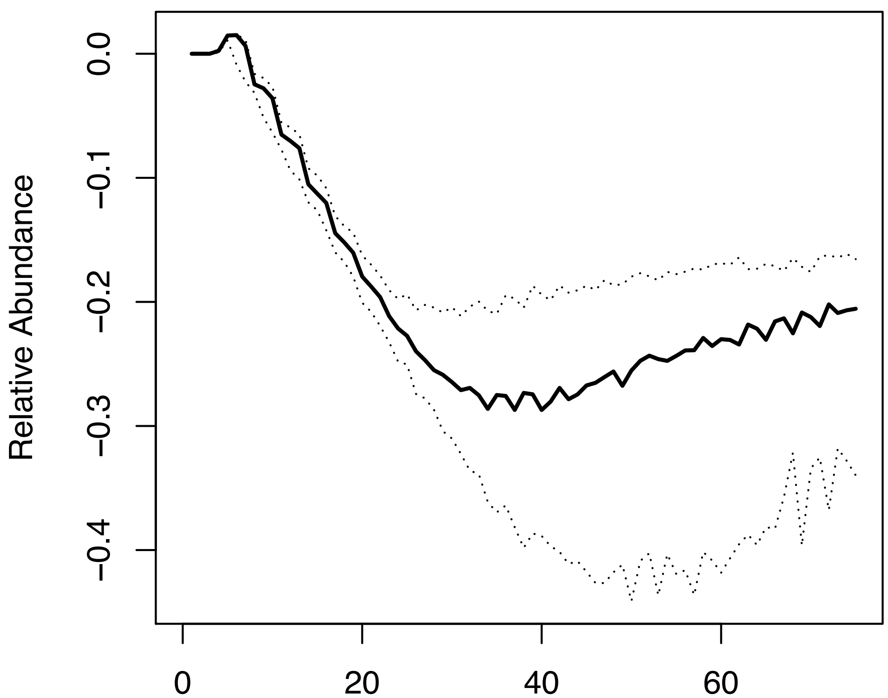
Action in
All Years



Action in
Critical Years

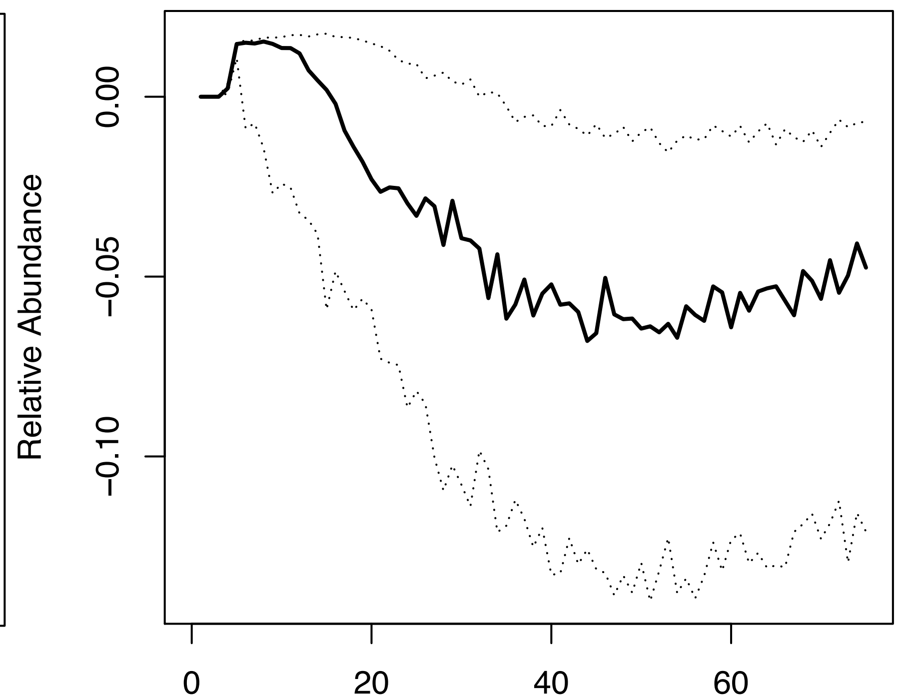
Preliminary Results
-1C Apr + 1.5C Sept & Reintro

Action 3 with Reintroduction



Action in
All Years

Action 4 with Reintroduction



Action in
Critical Years

Discussion Topics

- Is a 1C June for 1C August trade a reasonable assumption, what about 1C April for 1.5C Sept?
- What other temperature management actions seem interesting to evaluate?
- Hydrologic traces reflect historical hydrology – how can we update this analysis to reflect climate change?

What will the future hold?

PNAS

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SEE COMMENTARY

Anthropogenic warming has increased drought risk in California

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Edited by Jane Lubchenco, Oregon State University, Corvallis, OR, and approved January 30, 2015 (received for review November 22, 2014)

California is currently in the midst of a record-setting drought. The drought began in 2012 and now includes the lowest calendar-year and 12-mo precipitation, the highest annual temperature, and the most extreme drought indicators on record. The extremely warm and dry conditions have led to acute water shortages, ground-

which steered Pacific storms away from California over consecutive seasons (8–11). Although the extremely persistent high pressure is at least a century-scale occurrence (8), anthropogenic global warming has very likely increased the probability of such conditions (8, 9).

- Future precipitation deficits are more likely to be coupled with warm conditions that produce drought